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SYSTEMATIC BACTERIOLOGY.

System der Bakterien. Handbuch der Morphologie, Entwicklungsgeschichte und Systematik der Bakterien. Allgemeiner Theil. By W. Migula. Vol. i. Pp. 368; 6 plates. (Jena: Gustav Fischer, 1897.)

APPLIED or technical bacteriology in recent years has developed so rapidly, that in the rush after new discoveries the study of systematic bacteriology has been almost entirely neglected. With the introduction of Koch's methods the separation of bacteria was made an easy matter, and when it became evident that a large number of pathological lesions are caused by micro-organisms, bacteriology was introduced into the medical laboratories, and undoubtedly the pathological bacteriologist has greatly advanced our knowledge of the action of bacteria in health and in disease. Until Pasteur appeared, those lowly organisms had been unobtrusively studied in botanical laboratories, but the discoveries of this immortal genius revealed to all how great a share the bacteria have in the preservation of health and the causation of disease, in the sorrows and pleasures of life. Discovery after discovery in the causation of disease has led to triumph after triumph in prevention and cure; the study of fermentation has led to the perfection of important industries, and even now an appeal is made to the bacteria to keep our surroundings in a good sanitary condition. Bacteriology was so keenly studied by medical men that at one time there was almost a danger lest all micro-organisms were regarded as our foes, and yet their friendly acts greatly outweigh the harm that they do to us. Now, however, this is fully recognised, and just as at one time disease-producing bacteria were searched for, so at present the tendency is to seek after useful micro-organisms and to sing their praises. In this country, as usual, we are slow to encourage the study of applied bacteriology; in our midst it is yet fighting its way into medicine, and there is still an appalling ignorance of bacteriology even amongst the youngest physicians and surgeons; the British brewers are just beginning to see what Denmark and Germany saw years ago, and in agriculture we pin our faith on lectures and feeble examinations instead of opening research laboratories for the study of bacteriology as applied to the dairy and the soil. However, the records of other countries show us what practical bacteriology has achieved in a short time.

The never-ceasing discovery of new bacterial forms by men who have no knowledge or sympathy with systematic botany has led to serious confusion, especially in medical circles. It is their practice to describe an organism, at once to give it a name, often derived from the lesion it produces, and to claim for it a specific place in nature, without attempting to define its proper position in a systematic classification. The confusion about the choleraic vibrio is not yet entirely cleared away; thirty and more varieties have been described as different species, and now in the case of the diphtheria bacillus the number of pseudo-forms increases rapidly. The medical bacteriologist is

too much influenced by simple staining reactions, and morphological appearances or biological and chemical phenomena, and he distinguishes species by most inadequate tests. It is therefore a matter of congratulation to be able to welcome two works on bacteriology, founded upon botanical principles, such as Prof. Migula and Prof. A. Fischer have offered. Here we shall speak only of Prof. Migula's "System of Bacteriology."

The author begins with a concise critical account of the historical development of systematic bacteriology from Leeuwenhoek to our present time. It must be a relief to many that Prof. Migula considers it almost useless waste of thought to ponder over the question whether bacteria are plants or animals; since they must be placed somewhere, we may without hesitation classify them among the plants, not because they possess a vegetable nature, but because their nearest living allies are found among the plants. The different systems proposed by Cohn, Zopf, Flügge, de Bary, Hüppe, Eisenberg, Miquel, Fischer and others are discussed and criticised. A classification on the principle of fructification is impossible, because we cannot honestly accept the existence of arthrospores, and thus there is no *fundamentum divisionis*; nor can we classify bacteria according to their chemical, physical and physiological properties, as proposed by Eisenberg. Prof. Migula justly repudiates the extraordinary artificial and unnatural system of Miquel, which was founded upon the constancy of physiological properties. As it is a habit of medical bacteriologists, even at the present time, to distinguish species or varieties on such a principle, which has also been ably criticised by Prof. Marshall Ward, we advise them to glance at pp. 42 and 43, which should convince them of their error. Prof. Migula's system is as follows:—

BACTERIA.

Family I.—Coccaceæ.

- Species 1. Streptococcus = division in one plane.
- 2. Micrococcus = division in two planes.¹
- 3. Sarcina = division in three planes.
- 4. Planococcus = division in two planes; flagella.
- 5. Planosarcina = division in three planes; flagella.

Family II.—Bacteriaceæ.

- Species 1. Bacterium = no flagella.
- 2. Bacillus = completely surrounded by flagella.
- 3. Pseudomonas = polar flagella.

Family III.—Spirillaceæ.

- Species 1. Spirosoma = no flagella; rigid.
- 2. Microspira = 1, or 2-3 polar flagella; rigid.
- 3. Spirillum = 5-20 polar flagella; rigid.
- 4. Spirochaete = no flagella; flexible.

Family IV.—Chlamydobacteriaceæ.

- Species 1. Streptothrix.
- 2. Cladothrix.
- 3. Crenothrix.
- 4. Phragmidiothrix.
- 5. Thiothrix.

Family V.—Beggiatoaceæ.

- Species Beggiatoa.

The morphology of the bacterial cell is carefully described, and considerable attention is paid to the cell-membrane, which, according to Prof. Migula, is directly

¹ It is pleasing to note that the term "staphylococcus" does not occur in this system.

continuous with the flagella where they exist. The latter cannot be traced into the substance proper of the cell, a statement which the writer of this review, from his own studies, especially on the bacillus of tetanus, is not prepared to accept. The question whether bacteria possess a nucleus is discussed at length, and the author concludes that true nuclei have not been detected, and it is improbable that they exist. All the granules or structures hitherto described as nuclei, cannot possibly be regarded as such; this is clearly shown by Fischer's researches on bacterial plasmolysis. In studying the minute details of the bacterial cell, Prof. Migula rightly insists upon the absolute necessity of starting from the normal living micro-organism. Extremely interesting is the masterly discussion of the nature of the granules and vacuoles observed in the substance of the bacterial cell, of the origin of polar staining and segmentation. In this section the subject of plasmolysis is carefully considered. The granules so frequently observed he regards as the rudimentary nucleus of the bacterial cell, but he frankly admits that this view is based entirely on personal opinion. One of the best portions of the book is the section on the flagella, which recently have been diligently studied also by Fischer, who has proved that these fascinating structures are the motor-organs of the mobile micro-organisms, and who has attempted to classify the bacteria according to the arrangement and distribution of their flagella. Prof. Migula concludes that all flagellate schizophytes, excepting Spirochæta and Beggiatoa, are bacteria, and that different species belonging to the same family can be distinguished by their flagella; and herein all who have experience of flagella staining will agree with him: the number of flagella, their mode of insertion, and their shape and curves—all these points must be noted.

The growth and division of the bacterial cell is described with eloquent fulness. The mode of division is a generic character in the coccaceæ; it is constant, and a coccus dividing in one plane by no manner of means can be made to divide in two or three planes. But, furthermore, it is a fundamental distinctive feature between the coccaceæ and the other bacteria; for the latter divide only in one plane, and the division is always preceded by an elongation of the cell in a direction at right angles to the plane of division. Until recently it was stated that cocci are as long as they are broad, and that by such measurements they can be distinguished from the bacteria; but Prof. Migula insists that we must abandon this unsatisfactory distinction in favour of the one just enunciated. The bacteriaceæ always divide at right angles to their long axes, and we must therefore take exception to the statements, recently made in certain quarters, that the diphtheria bacillus divides parallel to its long axis. Of the branching of streptococcus chains he gives two satisfactory explanations: (1) occasionally in a long chain a coccus becomes twisted so that its plane of division is turned in a different direction; (2) a few links in the chain die, and are overgrown by the survivors. This branching therefore does not signify a mycelial ancestry. After division has taken place, the organisms may be arranged as diplo-cocci, strepto-cocci, tetra-cocci, or as sarcinæ; but it is absurd to use the terms diplo- and tetra-coccus as generic ones, for many organisms belonging to

different genera may present all these forms. The chapter on spore formation occupies fifty-three pages, and is a masterly account of the subject, from which a few points may be quoted. The so-called arthrospores cannot be distinguished from ordinary vegetative cells, and cannot therefore be regarded as spores, so that the endospore is the only recognised spore. Physiological properties, such as resistance against heat, desiccation, or antiseptics cannot decide the nature of a spore; the only true criterion is germination, a process differing in essence and in principle from ordinary vegetative proliferation by division. The formation and structure of the spore are described with a wealth of detail which omits no important fact. Broadly speaking, germination may occur in three ways: (a) the membrane of the spore remains unruptured, either persisting as the membrane of the young bacterium, or being dissolved during the process of germination; (b) the spore-membrane is ruptured at one or other pole, allowing the young bacterium to glide out; or (c) it is ruptured equatorially; but in each case there are numerous minor variations and deviations from the type, depending partly upon the conditions under which the germination is observed. A nucleus so far has not been demonstrated in the spore, although recently Hegler claimed to have done this. We must fully agree with Prof. Migula when he expresses the opinion that so long as we are ignorant of the natural conditions of bacterial growth, we are not in a position to use the faculty of spore formation for the purpose of systematic classification, for many bacteria which at present are described as asporogenous under more natural conditions than the gelatine or agar-agar tubes can supply, may actually form spores.

Everybody will turn with interest to the chapter on Pleomorphism and Variability, which opens with a historical account of the views held since Nægeli's time. Nægeli in almost unpardonable and unintelligible manner ignored all morphological and physiological characters of the bacteria, and became the master of the reckless apostles of pleomorphism. Their creed led the philosophic Buchner into the almost amusing error of proclaiming the identity of the hay bacillus and the anthrax bacillus, and caused the illustrious Billroth to blunder with his *Coccobacteria septica*. Prof. Migula insists that species must be determined by identity in development and growth and constancy of morphological characters; but as yet our microscopes are not perfect enough to detect the minutest morphological differences, and therefore for the present, in many cases, we must fall back upon biological characters. Varieties are by no means constant, and widely different forms may constitute a species. It is impossible here to discuss the question more fully; those who take an interest in such matters must consult the original.

In the last 100 pages the biological characters of the bacteria are discussed; the different nutrient media and the methods of cultivation; the formation of pigments (which are subdivided according to their solubility in water and alcohol); the products of fermentation and of metabolic activity, and the pathogenetic properties of the bacteria. To the medical bacteriologist the chapter on infective micro-organisms is an important one. For practical purposes it is proper to distinguish between pathogenetic and non-pathogenetic organisms, but this dis-

inction cannot be recognised in systematic bacteriology. Prof. Migula invites the botanist to follow the methods of the medical bacteriologist in the study of bacterial diseases of plants, which he regrets in most cases has been undertaken in a slipshod and careless manner. He gives a number of plant diseases, said to be due to bacteria, to expose the manner in which the subject hitherto has been approached. Anaerobiosis and phosphorescence, the thio-bacteria and ferruginous bacteria form the subjects of the next few chapters, and then we come to an interesting and concise account of the nitro-bacteria; the volume is concluded by two short chapters on the influence of heat and light on bacterial growth.

We may disagree with the author here or there, but we, and especially the medical bacteriologists, must welcome the appearance of this work. The volume is the result of Prof. Migula's own labours and studies pursued for many years with true German industry, and this enhances its value considerably. It is well written, and the language is not particularly difficult; the literary references at the end of each chapter are excellent. It is impossible to read the book without regretting that the second volume has not yet appeared. Six plates accompany the text, but, by an oversight, plates iv. and v. have been placed and numbered in wrong order, and must be transposed.

A. A. KANTHACK.

THE PHYSICAL PROPERTIES OF CRYSTALS.

Die fundamentalen physikalischen Eigenschaften der Krystalle in elementarer Darstellung von Dr Woldemar Voigt, o.o. Professor der Physik an der Universität Göttingen. (Leipzig: Veit and Co., 1898.)

PROF. VOIGT is well known for his researches into the physical properties of crystals. Not only is the mathematical theory of large parts of the subject due to him, but the experiments on which the theory is built were largely made by himself and Prof. Riecke, and many of the instruments used were invented or improved by him. His latest contribution to the science is a little book, half-way between a popular exposition and a technical treatise. Last year Prof. Voigt lectured at Göttingen on crystals to teachers in the upper classes of secondary schools, and these lectures form the basis of the book before us.

Prof. Voigt is a mathematician, and though the mathematics is here reduced to a minimum, he assumes a knowledge of the elements which his hearers doubtless possessed. A command not of facts and formulæ, but of mathematical and physical ideas and terms is required for a satisfactory study of the book. In particular, some familiarity with the use and transformation of co-ordinates is essential. In England, where the knowledge of elementary mathematics is widely spread, this little volume ought to find many readers, and a good translation is to be desired.

We have before us no mere text-book, but a book with an idea and a plan. Round the idea the facts are grouped, and one is carried on naturally from one set of properties to another. After a preliminary chapter on

the symmetry of crystal forms, the leading idea is developed in the second chapter. Prof. Voigt points out that, in investigating the relation between cause and effect, it is allowable to treat not only effects but causes as states of matter. For instance, electric phenomena produced by heat may be regarded as the relation between the temperature and the electrical state of a body. Temperature is determined by a scalar quantity, and the electrical state of any particle by a vector. This vector is, moreover, a so-called polar vector, *i.e.* one, like a translation, whose components change sign when the sense of all the coordinate axes is changed, in contradistinction to a so-called axial vector, whose components retain their signs. Temperature involving no direction, the direction of the vector can only be determined by the crystalline structure, and we should expect such a relation to be possible in acentric crystals possessing one single polar axis of symmetry, such as tourmaline. In fact, the pyro-electric properties of tourmaline have been known for 200 years.

Besides scalars and vectors there is a third kind of quantity, by which a state of tension or dilatation is characterised. It is determined by a magnitude and a straight line, undetermined in sense. Prof. Voigt calls such a quantity a *tensor*, and three mutually perpendicular tensors a *tensor-tripel*, giving in the preface his reasons for the adoption of a new term, and pointing out that in doing so he is merely extending the use of the word in quaternions. By means of these three kinds of quantities and their mutual relations, he is able to classify, in the manner indicated, the different phenomena. In every case we have two effects due to the same cause, and the primary effect is taken to represent the cause in its relation to the secondary effect. Each chapter after the second exhibits such a relation. We have an example of the relation between a scalar and a tensor-tripel in that between temperature and deformation, between a vector and a tensor-tripel in piezo-electricity, and numerous examples of two vectors; elasticity is treated as a relation between two tensor-tripels.

The method gives more than a mere classification, as the example shows. It enables us to say *à priori* whether a given body, isotropic or crystalline, is capable of exhibiting certain phenomena. In general the phenomena which are *à priori* possible, are *à posteriori* known to exist. In one case, however, referred to in Chapter iii., a set of phenomena represented by the relation between a scalar and an axial vector, theoretically possible in a large class of crystals, has never been observed, and it remains open to question whether the failure to observe pyromagnetic phenomena is due to an unknown point of theory or to unsuspected difficulties of observation.

In the chapter on the symmetry of crystals, Prof. Voigt takes three typical forms—Iceland spar (rhombohedron), tourmaline, and quartz—and he derives the two latter from the former by the simple process of joining together two "half rhombohedra." In spite of three excellent figures, the explanation would not be comprehensible without previous knowledge of the way in which the rhombohedra are to be divided. Even the simplest crystal forms are hard to understand without a